Tectonophysics 585 (2013) 3–12

Contents lists available at SciVerse ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Air and shipborne magnetic surveys of the Antarctic into the 21st century

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ARTICLE INFO

Article history:
Received 1 August 2011
Received in revised form 27 January 2012
Accepted 13 February 2012
Available online 24 February 2012

Keywords:
ADMAP
Geophysical surveys
Magnetic anomalies
Crustal studies of the Antarctic

ABSTRACT

The Antarctic geomagnetics' community remains very active in crustal anomaly mapping. More than 1.5 million line-km of new air- and shipborne data have been acquired over the past decade by the international community in Antarctica. These new data together with surveys that previously were not in the public domain significantly upgrade the ADMAP compilation. Aeromagnetic flights over East Antarctica have been concentrated in the Transantarctic Mountains, the Prince Charles Mountains – Lambert Glacier area, and western Dronning Maud Land (DML) — Coats Land. Additionally, surveys were conducted over Lake Vostok and the western part of Marie Byrd Land by the US Support Office for Aerogeophysical Research projects and over the Amundsen Sea Embayment during the austral summer of 2004/2005 by a collaborative US/UK aerogeophysical campaign. New aeromagnetic data over the Gamburtsev Subglacial Mountains (120,000 line-km), acquired within the IPY Antarctica's Gamburtsev Province project reveal fundamental geologic features beneath the East Antarctic Ice sheet critical to understanding Precambrian continental growth processes. Roughly 100,000 line-km of magnetic data obtained within the International Collaboration for Exploration of the Cryosphere through Aerogeophysical Profiling promises to shed light on subglacial lithology and identify crustal boundaries for the central Antarctic Plate. Since the 1996/97 season, the Alfred Wegener Institute has collected 90,000 km of aeromagnetic data along a 1200 km long segment of the East Antarctic coast over western DML. Recent cruises by Australian, German, Japanese, Russian, British, and American researchers have contributed to long-standing studies of the Antarctic continental margin. Along the continental margin of East Antarctica west of Maud Rise to the George V Coast of Victoria Land, the Russian Polar Marine Geological Research Expedition and Geoscience Australia obtained 80,000 and 20,000 line-km, respectively, of integrated seismic, gravity and magnetic data. Additionally, US expeditions collected 128,000 line-km of shipborne magnetic data in the Ross Sea sector.

1. Introduction

The geology of the ice-covered interior of the Antarctic is poorly known and inferences about its composition and history are based mostly on extrapolating scarce outcrops from the coastal regions towards the interior of the continent. The composite tectonic evolution of the continent beneath the Antarctic Ice Sheet involves great uncertainties due to the paucity of outcrops and geochronology data. However, aeromagnetic data can help constrain the interpretation of basement features and expand our geological knowledge of Antarctica. Anomalies arising from the magnetic character of rocks in the earth's crust have revealed many aspects of earth processes and

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0040-1951/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2012.02.017

geodynamics, and mapping them comprehensively has been a focus of many Antarctic expeditions for more than fifty years.

The first magnetic anomaly map for the Antarctic region south of 60°S combined over 1.5 million line-km of marine and aeromagnetic survey data collected by the international community from the IGY 1957–58 to 1999 (Golynsky et al., 2001, 2006a) and more than 5.8 million line-km of the satellite (Magsat) observations. It provides a unique window on basement geology, structural architecture and tectonic evolution of the Antarctic crust and the 5-km grid of the ADMAP map is available at www.geology.ohio-state.edu/geophys/admap. The CD of the survey data in the compilation was released to the World Data Centers in 2008 and incorporated into the World Digital Magnetic Anomaly Map and EMAG2 of NOAA (e.g. Maus et al., 2009).

The line coverage of marine and airborne surveys in the first ADMAP compilation is shown in Fig. 1, where large regional gaps in coverage are evident especially for the East Antarctic. Particularly large gaps are between the mountainous regions of Dronning Maud Land and the South Pole, As well as between Wilkes Land and Adélie Land. Very sparse coverage in Queen Mary Land and adjacent areas includes several historical reconnaissance profiles flown in the late 1950s, local narrow surveys along the coastal region and small surveys over the Antarctic oases such as Bunger Hills and the Windmill Islands. The Ross Ice Shelf area also was visited by only several profiles that were gathered in early 1960s, even though geophysical information from this region would contribute greatly to better understanding the West Antarctic Rift system that was mapped largely by seismic data over the Ross Sea shelf (Behrendt et al., 1991; Brancolini et al., 1991; Cooper and Davey, 1987; Hinz and Block, 1984; Hinz and Kristoffersen, 1987; Zayatz et al., 1990).

The most poorly mapped offshore region includes the Amundsen Sea sector and eastern part of the Ross Sea, where the data were mostly obtained from random tracks with orientations that are rarely optimum for investigating the magnetic fabrics. The eastern Weddell Sea and western Riiser–Larsen Sea require additional surveys to better constrain the break-up of Antarctica and Africa and determine the spatial extent of the Maud Rise submarine igneous province.

To help fill in the coverage gaps between the near-surface surveys, the satellite magnetic observations at roughly 400-km altitude from the 6-month Magsat mission were used. However, these satellite data were collected during austral summer and fall periods, and thus are maximally corrupted by external magnetic field variations. Much cleaner Antarctic satellite magnetic observations from several austral winters are now available from the Ørsted and CHAMP missions at altitudes of about 600 and 400 km, respectively (Kim et al., 2004, 2007). The measurement accuracies of these observations are also better than Magsat's by roughly an order of magnitude.

Effective estimates of near-surface anomalies in the coverage gaps can be obtained by optimized the inversion of the satellite data to match the near-surface anomaly observations around the gap's perimeter (Kim et al., 2004, 2007). Simulations found that the newer satellite data improve gap estimates by nearly 75% relative to the Magsat near-surface anomaly predictions. Limited testing with data from new surveys conducted since 1999 shows that the gap predictions from

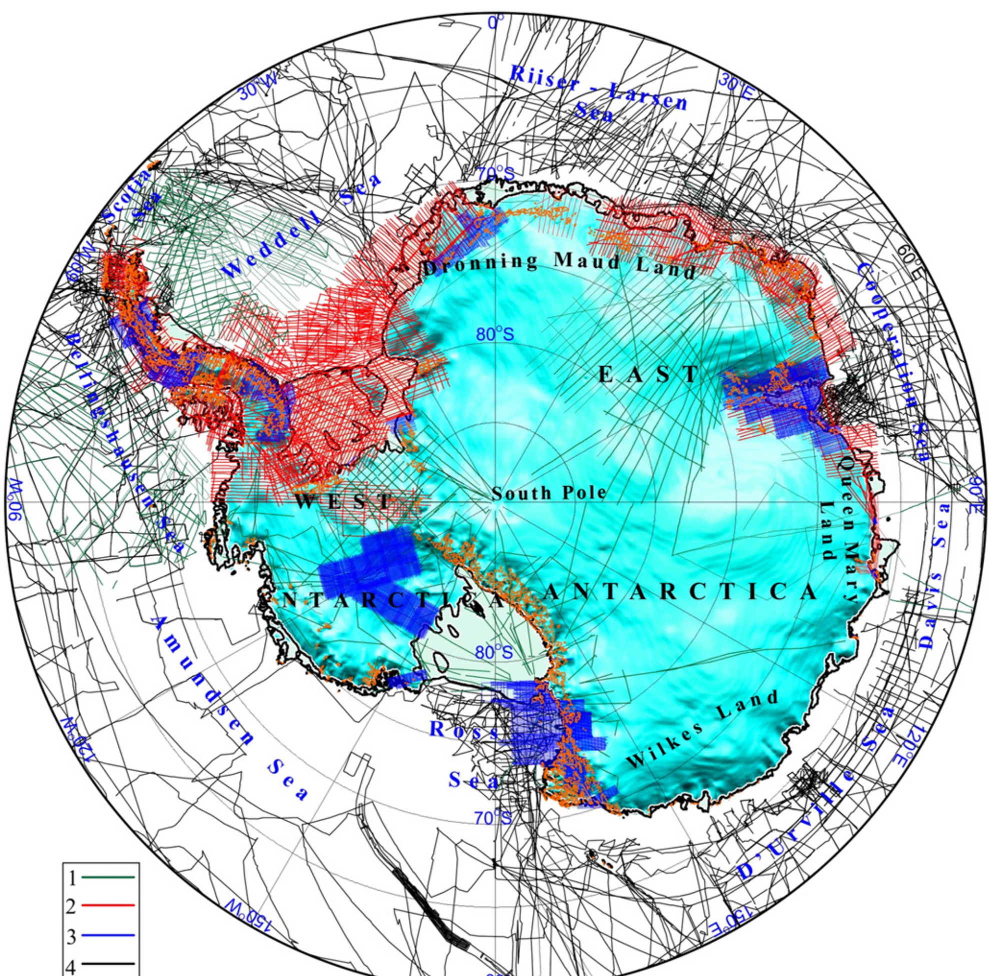

Fig. 1. Line coverage of the ADMAP-1 magnetic surveys superimposed on a shaded relief of the sub-ice topography of Antarctica (Golynsky et al., 2001). 1 — Airborne surveys with flight-line spacing ~50 km; 2 — airborne surveys with flight-line spacing ~20 km; 3 — airborne surveys with flight-line spacing ~5 km; 4 — shipborne surveys.